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QUANTIFYING THE DIGITAL ECONOMY ACCORDING TO THE PROPOSED FRAMEWORK

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Methods. The article is based on a thorough analysis of data on the development of the digital economy, obtained from experts, researchers and partners specializing in the collection and processing of statistical data. The concept proposed in the article is formed based on both the basic definition of the digital economy and the methodology of measuring its scale basing on the calculation of added value. The digital economy estimation method is based on the use of national accounts and reflects the digital economy in the general context of gross domestic product (GDP).

Results. The article examines the role of digital technologies in the socio-economic development of society. The changes that the modern model of interaction between business and society undergoes under the influence of digitalization processes are demonstrated. Special attention is paid to the research of existing systems for measuring the scale of the digital economy. The possibility of applying an approach to the assessment of the digitalization of the economy, which is based on the macroeconomic approach of consumption-output, proposed by W. Leontief, is considered. For its implementation, available data from the system of national accounts were used, namely: information on sixteen economies in Asia, Europe, North America and the Pacific region, including Australia. The study identified digitized sectors around the core perimeter of the digital economy, and predicted that countries with high imports of digital products, as well as industries that are highly dependent on the functioning of core digital sectors, are likely to have lower digital economy scores than others.

Novelty. An improved methodological approach to measuring the scale of the digital economy is proposed, which consists in estimating its share in the total GDP of the country based on the calculation of the added value of a set of key digital products created within the national economy.

Practical value. The results of the study are relevant to modern global problems, as they form a comprehensive statistical perspective of the review of the development of the digital economy.

Keywords: digital economy, measurement framework, GDP, Leontief coefficient, matrix operations.

Statement of problem. Over the years, digital technology has advanced at a relentless pace, resulting in components that are much smaller, more efficient, and less expensive than their counterparts.

Digital technologies in the form of miniature computing, communications and storage devices now play a prominent role in modern life. In response, developers, academia, government, and even private institutions have begun developing methods to measure digitization using factual information about private and public transactions involving digital goods and services. The collective value of such products and the resulting interactions is referred to as the «digital economy».

The paper provides an analysis of a simple and practical measurement framework for the digital economy, fundamentally based on input-output analysis according to Leontief (1, p.18), using available national accounts data. The framework is used by 16 economies across Asia, Europe, North America and the Pacific, including Australia, to create an assessment of the digital economy.

Survey data also draws on official statistical agencies that participate in the Bank's statistical and analytical capacity building initiatives. Establishing a definition of the digital economy is an important first step leading to the development of methods to measure it (2, p.17).

Although the digital economy may be considered a recent phenomenon, traditional national reports and statistics actually offer a rich source of data to capture the concept.

The measurement method uses national accounts and reflects the digital economy in the overall context of gross domestic product (GDP).

Theoretical background. According to Dinan and Scheiner, although GDP in general does not provide a comprehensive measure of economic well-being, there is no doubt that it provides information that is closely related to well-being. (3, p.43).

Thus, measuring the digital economy in terms of its contribution to the economy's GDP provides a suitable lower bound for assessing its welfare effects on the wider economy. In general, the measurement is made using input-output analysis, which shows that the value-added contribution of the digital economy is given by the total GDP of the digital industry, plus the part of the GDP of the non-digital industry that enables the production of the digital industry.

The Organization for Economic Co-operation and Development (OECD) and the United States Bureau of Economic Analysis (USBEA) have similarly proposed a measurement method based on national accounts (4, pp. 35–37). In particular, the OECD and USBEA propose an approach that uses a supply and use framework.

The former includes the entire value of transactions related to digital platforms, as well as the value of the platforms themselves, while the latter only calculates margin and broker fees on such transactions.

Another measurement framework is that of Brynjolfsson et al, who complement national accounts statistics by proposing a well-being-based measurement called GDP-B (5, pp.7250–7255).

Meanwhile, Huawei and Oxford Economics (2017) used digital spillover effects to estimate the global digital economy, which they estimate to be $11.5 trillion (6, p.12).

Aim of the paper. The purpose of the article is to develop a methodological approach to measuring the digital economy.

Materials and methods. *Disaggregating Gross Domestic Product across Users.* We consider the core evaluative framework of the digital economy, which defines digital products as goods and services whose primary function is the generation, processing and/or storage of digital data. (7, pp. 31–37).

Primary producers of such products are considered digital industries. The framework identifies key digital products that can be summarized into five main products: (i) hardware, (ii) software publishing, (iii) web publishing, (iv) telecommunications services, and (v) specialized and support services.

The length of time a product group transitions before becoming purely digital varies by product concept and life cycle. It can also vary by location, depending on factors such as the degree of trade liberalization, the ability to participate in the necessary stages of production, and consumer demand.

As for the exact point in time when virtually every unit of a product group delivered in a given economy has become digital, a conservative approximation based on published research may be the most convenient option.

The models included in the proposed measurement framework are based on input-output analysis, mainly using Leontief coefficients to directly measure sector interdependence in terms of value added contribution. The components of the digital economy measurement framework (Fig. 1).

Finding. We will consider the stages of deriving the digital GDP equation (GDP = gross domestic product; t hroughout this report, digital GDP (or $GDP_{digital}$) refers to the gross value-added (GVA) of the digital sector).

Inverse Leontief coefficients, show that the total output x of a standard input-output table (IOT) can be briefly represented as a Leontief function.

Gross outputs x in a standard input-output table (IOT) can be concisely represented as a function of the Leontief Inverse. A standard input-output table (IOT) is generally comprised of three quadrants (Fig. 2)

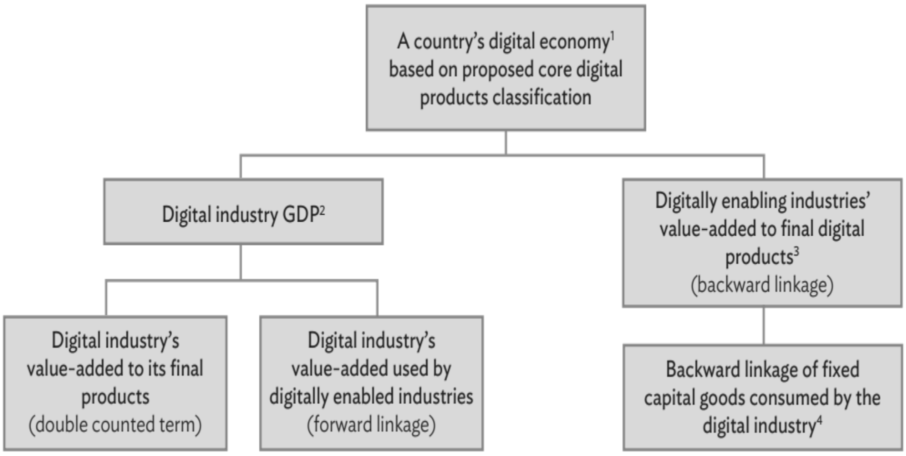

Figure 1: Proposed Digital Economy Measurement Framework
Source: Methodology of the Digital Economy Measurement Framework study team, using Leontief (1936) coefficients.

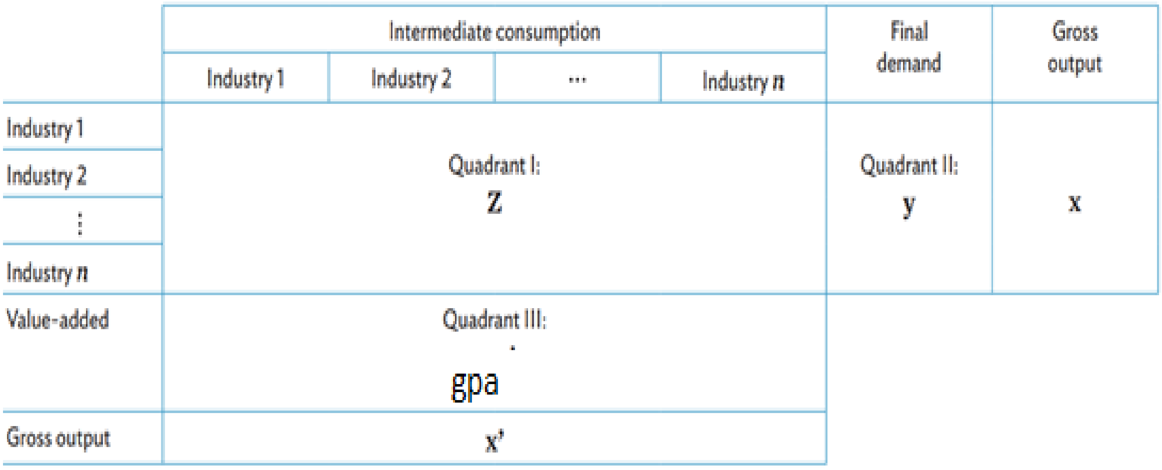

Figure 2: Standard Industry Input-Output Table

Inverse, $(1 - A)^{-1}$ and final demand, y. Equation (1) describes this relationship.

$$x = (1 - A)^{-1}\ y \qquad (1)$$

Further mathematical manipulations would also allow derivation of a similar equation for economy-wide GDP (8, pp.78-80). For brevity, let the Leontief inverse, $(1 - A)^{-2}$ B. A direct value-added coefficient vector is defined as

$$P = (p_1\ p_2\ ...\ p_n) = \left(\frac{gpa_1}{x_1}\ \frac{pga_2}{x_2} ... \frac{gpa_n}{x_n} \right) \qquad (2)$$

where, gpa, j = 1, 2, …., n, refers to the gross value-added (GPA) generated by industry j and x_j refers to the gross output of the same industry j. Thus, each entry in P is the ratio of industry j's GPA to its own output. It is shown below that pre-multiplying P from Equation (2) to x from Equation 1 would yield an expression that calculates economy-wide GDP via the production approach (Equation 3). 18 Knowing how to derive economy-wide GDP using the p By formulation in Equation 6 is the first step in understanding how a more disaggregated digital GDP is quantified (9, p.25).

$$px = vB\ y$$

$$\rightarrow gpa_1 + gpa_2 + \cdots + gpa_n = \sum_{i=1}^{n} \sum_{j=1}^{n} p_i b_{ij}\, y_j$$

$$= \text{economy-wide GDP} \qquad (3)$$

The economy-wide GDP that is calculated using Equation (3) can be further disaggregated to an n × n matrix where an industry's backward and forward linkages can be derived. In particular, this matrix will show an industry's sources (backward linkages) and destination (forward linkages) of value-added. In the context of the digital economy, these sources and destinations respectively refer to industries on which digital sectors are dependent (10, p.23), and industries that are enabled by digital sectors. Simple matrix operations involving the $\ddot{p}$, B, and y matrices are performed to get an industry's backward and forward linkages. Diagonalizing the direct value-added coefficient vector from Equation (2) and the final demand vector results in matrices p̈ and ÿ below.

$$\ddot{p} = \begin{bmatrix} p_1 & 0 & \cdots & 0 \\ 0 & p_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & p_n \end{bmatrix}; \quad \ddot{y} = \begin{bmatrix} y_1 & 0 & \cdots & 0 \\ 0 & y_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & y_n \end{bmatrix};$$

Pre-multiplying $\ddot{p}$ to B and then post-multiplying the matrix product to $\ddot{y}$ gives the $\ddot{p}$ B $\ddot{y}$ matrix in Equation 4, which is an n × n matrix that disaggregates the scalar economy wide GDP across all industries that use and supply value-added.

$$\ddot{p}\,B\,\ddot{y} = \begin{bmatrix} p_1 & 0 & \cdots & 0 \\ 0 & p_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & p_n \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix} \begin{bmatrix} y_1 & 0 & \cdots & 0 \\ 0 & y_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & y_n \end{bmatrix}$$

$$\ddot{p}\,B\,\ddot{y} = \begin{bmatrix} p_1 b_{11} y_1 & p_1\, b_{12}\; y_2 & \cdots & p_1\, b_{1n}\; y_n \\ p_2 b_{21} y_1 & p_2\, b_{22}\; y_2 & \cdots & p_2\, b_{2n}\; y_n \\ \vdots & \vdots & \ddots & \ddots \\ p_n\;\; b_{n1} y_1 & b_{n2} & \cdots & p_n\, b_{nn}\; y_n \end{bmatrix} \quad (4)$$

Where the rows of the $\ddot{p}$ B $\ddot{y}$ matrix correspond to the distribution of the use of added value created from a particular industry across all industries of the economy. And the columns correspond to the division of the contribution of added value of all sectors of the economy to the production of final goods and services of a specific industry.

Thus, the summation of all the entries in the column leads to the cost of the final products of the industry. A column-by-column tracing of the $\ddot{p}$ B $\ddot{y}$ matrix shows the lagged industry linkages.

Quantifying the digital economy in the n-industrial economy. Consider the case when the formation of the total fixed capital of the digital economy is integrated n In an industrial economy. To illustrate, the dimension of the vector of ratios, let r be the ratio vector of gfcf used by the digital industry corresponding to the final demand. Consequently, this is diagonalized as rˆ to form an n × n matrix.

Correspondingly, this is diagonalized as rˆ, to form an n × n matrix.

$$k = \begin{bmatrix} k_1 \\ k_2 \\ \vdots \\ k_n \end{bmatrix} \quad \ddot{k} = \begin{bmatrix} k_1 & 0 & 0 & 0 \\ 0 & k_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & k_n \end{bmatrix}$$

Similarly, the matrix $\ddot{p}$ B $\ddot{y}$ $\ddot{k}$ will have dimension n × n as shown below:

$$\ddot{p}\ \mathrm{B}\ \ddot{y}\ \ddot{k} = \begin{bmatrix} p_1 b_{11} y_1 & p_1 b_{12} y_2 & \cdots & p_1 b_{1j} y_j & \cdots & p_1\, b_{1n}\ y_n \\ p_2 b_{21} y_1 & p_2\, b_{22}\ y_2 & \cdots & p_2 b_{2j} y_j & \cdots & p_2\, b_{2n}\ y_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ p_j b_{j1} y_1 & p_j\, b_{j2}\ y_2 & \cdots & p_j b_{jj} y_j & \cdots & p_j\, b_{jn}\ y_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ p_n b_{n1} y_n & p_n\, b_{n2}\ y_2 & \cdots & p_n b_{nj} y_j & \cdots & p_n\, b_{nn}\ y_n \end{bmatrix} \begin{bmatrix} k_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & k_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & 0 & k_j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & k_n \end{bmatrix}$$

$$\begin{bmatrix} k_1 p_1 b_{11} y_1 & k_2\, p_1 b_{12} y_2 & \cdots & k_j p_1 b_{1j} y_j & \cdots & k_n p_1\, b_{1n}\ y_n \\ k_1 p_2 b_{21} y_1 & k_2 p_2\, b_{22}\ y_2 & \cdots & k_j\, p_2 b_{2j} y_j & \cdots & k_n p_2\, b_{2n}\ y_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ k_1 p_j b_{j1} y_1 & k_2\, p_j\, b_{j2}\ y_2 & \cdots & k_j p_j b_{jj} y_j & \cdots & k_n\, p_j\, b_{jn}\ y_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ k_1 p_n b_{n1} y_n & k_2\, p_n\, b_{n2}\ y_2 & \cdots & k_j p_n b_{nj} y_j & \cdots & k_n p_n\, b_{nn}\ y_n \end{bmatrix}$$

The Core Digital Economy Equation. The core digital economy equation (Equation 6) is derived by consolidating Equation 5 with the value of the backward linkage of fixed capital goods consumed by the digital industry. In Equation 10, the «agg» subscripts are suppressed for notational simplicity.

$$GDP_{digital} = \mathrm{I}^{t}\ \ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg}\ \varepsilon_1 + \mathrm{I}^{t}\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})^T\ \varepsilon_1 - [dig\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})]^T\ \varepsilon_1 \quad (5)$$

Equation (5) captures all contemporaneous input-output transactions with respect to exogenous final demand.

$$GDP_{digital} = \mathrm{I}^{t}\ \ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg}\ \varepsilon_1 + \mathrm{I}^{t}\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})^T\ \varepsilon_1 - [dig\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})]^T\ \varepsilon_1 + (I-\varepsilon_1)^T \ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg}\ \varepsilon_2$$

$$GDP_{digital} = \mathrm{I}^{t}\ddot{p}\ B\dot{y}\varepsilon_1 + \mathrm{I}^{t}\ (\ddot{p}\ B\dot{y})^T\varepsilon_1 - [dig\ (\ddot{p}\ B\dot{y})]^T\varepsilon_1 + (I-\varepsilon_1)^T\ddot{p}\ B\dot{y}\ddot{k}\ \varepsilon_2 \quad (6)$$

The first term - $\mathrm{I}^{t}\ \ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg}\ \varepsilon_1$ directly calculates the backward linkage related to the digital industry while the second term – $\mathrm{I}^{t}\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})^T\ \varepsilon_1$, gives the forward linkage. To account for the double-counted term, the diagonal entry in the $\ddot{p}\ B\dot{y}$ matrix that corresponds to the digital industry is removed, which is why $[dig\ (\ddot{p}_{agg}\ B_{agg}\ \dot{y}_{agg})]^T\ \varepsilon_1$ is subtracted in GDP digital. An "eliminator vector" ε_1 is used to mathematically eliminate entries that should not be included in calculations.

The n × 1 eliminator vector ε_2 is post-multiplied to $(I-\varepsilon_1)^T\ddot{p}\ B\dot{y}\ddot{k}$ to arrive at a value for the backward linkage of fixed capital goods consumed by the digital industry.

*Limitations of the Framework***.** The framework presented in this study relies on official and reliable published secondary data sources. Therefore, there is a limitation to ensure consistency and accuracy of all data.

This framework does not include the total value of online sales of non-digital goods. Instead, only the value contribution of digital products (or digital industries) involved in such transactions is recorded. As the scope of digital products is at the narrowest level, it excludes the digitally dependent economy, which includes the added value of sectors that are critically dependent on digital sectors.

The measurement framework is flexible for calculating this. Also, the measurement framework that estimates the value of the digital economy as a percentage of national GDP represents another area of limitation. Since an economy's GDP excludes imports, estimates of the digital economy also exclude them (11, p.78).

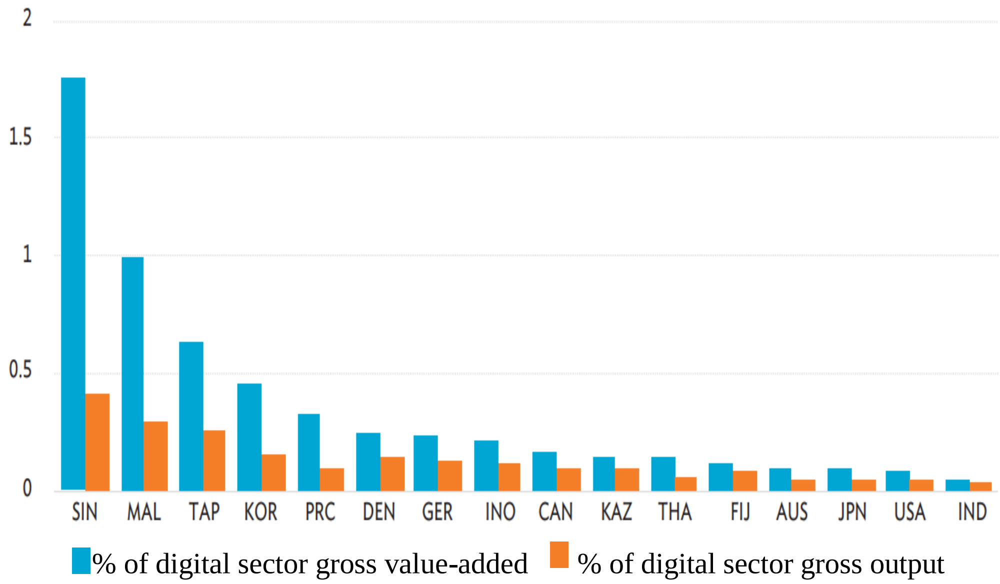

Figure 3: Imports of Digital Sectors, 2022

Source: Calculations of the Digital Economy Measurement Framework study team, using the 38-sector Asian Development Bank Multiregional Input-Output Tables 2022.

This may lead to a somewhat underestimation of the digital economy, especially for economies with digital sectors that have relatively high imports, such as Singapore; Malaysia; and Taipei, China as shown in the picture.

Conclusion. At this point, the proposed framework for measuring the digital economy tries to focus on the emerging products and industries of the digital age. frame

Measures the digital economy's share of GDP attributable to the economy's total GDP, which is accounted for by the contribution of value added to a defined set of key digital products, consistent with the digital economy.

Using national accounts data from 16 economies in different regions of the world, the results are clear. Despite the narrow definition adopted in the framework, the digital economy accounts for a significant part of the GDP of all sampled economies (approximately 2% to 9%). However, characterizing the role of the digital economy. Varies in different economies - some act more as value-added providers in the economy, while others act as consumers. As digital technologies play different roles in non-digital products, measuring the digitally dependent economy allows for a more comprehensive understanding of the digital economy in general. Therefore, economies with high imports of digital products, as well as economies with industries that depend heavily on core digital sectors, are likely to have smaller digital economy estimates than others. Digital technologies are transforming the way businesses operate and how societies interact.

References

1. Leontief, W. (1936). Quantitative Input and Output Relations in the Economic System of the United States. Review of Economics and Statistics. P.18;https://doi.org/10.2307/1927837

2. Asian Development Bank (ADB). (2021). Key Indicators for Asia and the Pacific Database. Regional Tables: Economy and Output, Gross Domestic Product. p.17.

3. Dynan, K., & Sheiner, L. (2018). GDP as a Measure of Economic Well-Being. utchins Center Working Paper. p. 43. https://www.brookings.edu/wp-content/ uploads/2018/08/WP43-8.23.18.pdf.

4. Mitchell, B. (2019). PSTN (Public Switched Telephone Network): The History and Current Relevance of Landline Phone Service. Lifewire. 13 December pp. 35-37. https://www.lifewire.com/pstn-public-switched-telephone-network-818168.

5. Byrnjolfsson, E., Collis, A., & Eggers, F. (2019). Using Massive Online Choice Experiments to Measure Changes in Well-Being. Proceedings of the National Academy of Sciences. 116. pp. 7250-7255.

6. Huawei and Oxford Economics. (2017). Digital Spillover: Measuring the True Impact of the Digital Economy. https://www.huawei.com/minisite/gci/en/digital-spillover/ index.html p.12.

7. Capturing the digital economy – a proposed mesurement framerwork and its applicating. A Special Supplement to Key Indicators for Asia and the Pacific, 2022, Asian Development Bank, pp. 31-37. https://doi.org/10.22617/fls210307-3

8. Ahmad, N., & Schreyer, P. (2016). Measuring Digitalised Economy. OECD Statistics Working Papers. No. 7. pp. 78-80.

9. Raa, T. (2006). The Economics of Input-Output Analysis. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511610783. P.25.

10. N. Ahmad & J. Ribarsky. (2018). Towards a Framework for Measuring the Digital Economy. 16th Conference of the International Association of Official Statisticians (IAOS). Paris: OECD. P.23.

11. Lund, J. Manyika, J. Woetzel, J. Bughin, M. Krishnan, J. Seong, & M. Muir. (2019). Globalization in Transition: The Future of Trade and Value Chains. McKinsey & Company. 16 January. P.78.

КІЛЬКІСНА ОЦІНКА ЦИФРОВОЇ ЕКОНОМІКИ ЗГІДНО З ПРОПОНОВАНОЮ СИСТЕМОЮ ВІМИРЮВАННЯ

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Методологія дослідження. Стаття побудована на ретельному аналізі даних розвитку цифрової економіки, отриманих від експертів, дослідників і партнерів, що спеціалізуються на зборі та обробці статистичних даних. Концепція, запропонована в статті, сформована за рахунок як базового визначення цифрової економіки, так і методології вимірювання її масштабу, базованого на розрахунку доданої вартості. Метод оцінки цифрової економіки ґрунтується на використанні національних рахунків та відображає цифрову економіку в загальному контексті валового внутрішнього продукту (ВВП).

Результати. У статті досліджено роль цифрових технологій у соціально-економічному розвитку суспільства. Продемонстровано зміни, яких зазнає сучасна модель взаємодії бізнесу та суспільства під впливом процесів діджиталізації. Особливу увагу приділено дослідженню існуючих систем виміру масштабу цифрової економіки. Розглянуто можливість застосування підходу до оцінки цифровізації економіки, який базується на макроекономічному підході витрати-випуск, запропонованому В. Леонтьєвим. Для його імплементації використано доступні дані системи національних рахунків а саме: інформацію за шістнадцятьма економіками в Азії, Європі, Північній Америці та Тихоокеанському регіоні, включаючи Австралію. Дослідження показало ідентифікацію діджиталізованих секторів навколо основного периметра цифрової економіки, а також прогноз щодо того, що країни з великим імпортом цифрових продуктів, а також з галузями, які сильно залежать від функціонування основних цифрових секторів, ймовірно, матимуть менші оцінки цифрової економіки, ніж інші.

Новизна. Запропоновано удосконалений методологічний підхід до вимірювання масштабу цифрової економіки, який полягає в оцінці її частки в загальному ВВП країни на основі обчислення доданої вартості набору ключових цифрових продуктів, створених у межах національної економіки.

Практична значущість. Результати дослідження мають відношення до сучасних глобальних проблем, оскільки формують комплексну статистичну перспективу огляду розвитку цифрової економіки.

Ключові слова: цифрова економіка, система вимірювання, ВВП, коефіцієнт Леонтьєва, матричні операції.

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